DOCUMENT RESUME

ED 118 440 SE 020 294

AUTHOR Kletsky, E. J.
TITLE Simulation of Neural Firing Dynamics: A Student Project.
PUB DATE Jun 75
NOTE 10p.; Paper presented at the Annual Meeting of the American Society for Engineering Education (Colorado State University, Ft. Collins, Colorado, June 16-19, 1975); Occasional small type in figure material

EDRS PRICE MF-$0.83 HC-$1.67 Plus Postage
DESCRIPTORS Algorithms; *Biophysics; Computers; Engineering; *Engineering Education; Graduate Study; Higher Education; Neurology; *Simulation; *Student Projects; *Systems Analysis

ABSTRACT

This paper describes a student project in digital simulation techniques that is part of a graduate systems analysis course entitled Biosimulation. The students chose different simulation techniques to solve a problem related to the neuron model. (MLH)

****
* Documents acquired by ERIC include many informal unpublished *
* materials not available from other sources. ERIC makes every effort *
* to obtain the best copy available. Nevertheless, items of marginal *
* reproducibility are often encountered and this affects the quality *
* of the microfiche and hardcopy reproductions ERIC makes available *
* via the ERIC Document Reproduction Service (EDRS). EDRS is not *
* responsible for the quality of the original document. Reproductions *
* supplied by EDRS are the best that can be made from the original. *
****

ED118440

U S DEPARTMENT OF HEALTH,
EDUCATION & WELFARE
NATIONAL INSTITUTE OF
EDUCATION

THIS DOCUMENT HAS BEEN REPRODUCED EXACTLY AS RECEIVED FROM THE PERSON OR ORGANIZATION ORIGINATING IT. POINTS OF VIEW OR OPINIONS STATED DO NOT NECESSARILY REPRESENT OFFICIAL NATIONAL INSTITUTE OF EDUCATION POSITION OR POLICY

EVENT NUMBER 2610

AMERICAN SOCIETY FOR ENGINEERING EDUCATION
ANNUAL CONFERENCE, JUNE 16-19, 1975

COLORADO STATE UNIVERSITY
FT. COLLINS, CO 80521

TITLE OF PAPER: SIMULATION OF NEURAL FIRING DYNAMICS:
A STUDENT PROJECT

NAME OF AUTHOR: E. J. KLETSKY
ASSOC. PROFESSOR OF SENSORY SCIENCE

ADDRESS: INSTITUTE FOR SENSORY RESEARCH
SYRACUSE UNIVERSITY
SYRACUSE, NY 13210

SE 020 494

Introduction

Among the graduate offerings of the Institute for Sensory Research in the area of systems analysis is a course in Biosimulation. An integral part of the course is a student project devoted to the application of digital simulation techniques. Difficulties arise in the choice of these projects because of the wide diversity of student backgrounds and because of different levels of computer skill. I would like to share with you my experience in attempting to overcome some of these difficulties.

As a student project we chose a relatively simple, but realistic, problem having no known analytic solution. Concentration would be on the simulation rather than on difficulties inherent in a complex problem. All students solved the same problem but were allowed to choose a digital simulation technique based on their individual backgrounds, level of computer expertise, availability of computer resources, and their personal interest in the problem. Class format was essentially a seminar with each student giving an oral presentation midway in the project and at completion. The mid-project presentations provided an opportunity for students to compare solution techniques and implementations, and to discuss real or imagined obstacles. Final presentations were aimed at comparing computed results as well as discussing the effectiveness of individual simulations in terms of direct cost, accuracy, and programming difficulty.

The Problem

The problem chosen involves firing dynamics of the simple neuron model shown in Fig. 1. Specifically, the simulation was to determine characteristics of the spike train produced when summated excitatory post synaptic potentials (EPSPs) interact with a dynamic threshold. EPSPs, each with an

exponential tail of known time constant, occur randomly with inter-event times controlled by a Poisson process. An output spike is generated when the summed EPSPs exceed threshold. After each spike an absolute refractory period (ARP) is entered during which time the threshold is infinite. Following the ARP, threshold recovers as K/t toward its resting value.

Implementations

Figure 2 summarizes the diversity of student backgrounds as well as the various computers and program types chosen. The large computers, IBM 370 and PDP 10, are part of the Syracuse University Computing Center and were used in both the batch and terminal modes. The LINC 8 computer is located within the Institute for Sensory Research, where many of the students are graduate assistants, and was available at no cost.

Algorithms of three main types were chosen. They included a straightforward calculation that proceeded point-by-point in time; an interesting time calculation that skipped over portions of time where threshold crossings could not occur; and a rather novel table look-up program based on the shape invariance of a sum of exponentials of equal time-constants. More adventuresome students combined various features of these algorithms. Simplified flow charts for the "Modified Interesting Time" and "Table Lookup" programs are shown in Figs. 3 and 4 respectively.

In the Modified Interesting Time program, a calculation is made at adjacent sample points to determine geometrical conditions. Five conditions are recognized: onset crossing, diverging, converging, intersample crossing, and possible tangency. In the latter two situations, a smaller sampling interval is chosen to more closely determine the time of threshold crossing. Thus the program dynamically selects an appropriate sampling interval. When

conditions exclude the possibility of a threshold crossing, the program advances time to the next interesting event, namely the onset of a new EPSP.

The Table Lookup program of Fig. 4 takes advantage of the fact that the sum of exponentials, each with the same time-constant, is an exponential having the same time-constant but a different scale factor. The program consists of two permanent tables. One stores values of the exponential function at equally spaced points in time; the second stores values of the absolute refractory period and the K/t recovery function using the same time increment. Pointers are set to the head of each table and the tables compared entry by entry. If a crossing occurs (THD entry = EPSP entry times EPSP multiplier), the threshold pointer is returned to the head of its table, an output event is generated, and the comparison between tables is continued. When a new EPSP arrives, the EPSP multiplier is updated and the EPSP pointer is returned to the head of its table. Comparison between tables continues as before. This Table Lookup program is essentially a point-by-point program but with a particularly fast and simple computational algorithm.

Simulation Outputs and Results

Output formats varied among students, and ran the gamut from exhaustive tabular values of threshold and generator potential at each sample point to summaries based on spike generation times. An example of the latter type is shown in Fig. 5. This output is from a run made with the Modified Interesting Time program. The number of EPSPs to be processed and the average rate of occurrence are entered as parameters. Each line of the printout corresponds to the generation of a spike. Each X represents an EPSP that has occurred since the last spike. The number at the end of the line is the inter-spike interval. The output report concludes by giving the total number of EPSPs,

the total number of spikes generated, the time period simulated, the average EPSP rate, and the average firing rate.

A completely different output report was generated using the CSMP (Continuous System Modelling Program) program. This is a line-printer graphical display of both the generator potential and threshold as a function of time. Figure 6 shows a short segment of this report covering about 10 milliseconds of real time. The left column is the generator potential as a function of time; the right column is the threshold. The high flat portions occur during the ARP. Paging format in the line printer creates the blank portion across the center.

A very exciting and satisfying aspect of the project occurred when individual results were pooled and plotted. Figure 7 is a pooled plot of average firing rate as a function of average EPSP rate. Results for all seven students are plotted. The only major deviation is for the data represented by open diamonds. The fall-off at high EPSP rates is due to sampling errors.

Conclusions

This student project resulted in a number of accomplishments. First, it acted as a vehicle to uncover many aspects of digital simulation. It was an introduction to practical computing for some; an extension of computing knowledge for others. It allowed the comparison of a number of high-level computing languages and programming techniques. It provided a practical seminar in oral presentation and in program documentation. Finally, the actual results obtained are a step in the solution of an important problem in neural dynamics related to on-going research at the Institute.

The project generated an unusual amount of student enthusiasm and provided experience in a significant and non-trivial simulation study. Each student, regardless of background, was able to achieve easily comparable minimal results, yet all were challenged at their own level of competence.

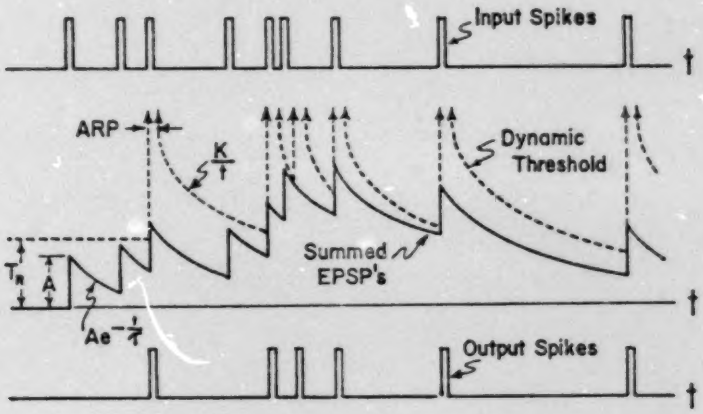

Figure 1

BACKGROUND			IMPLEMENTATION	
GRADUATE LEVEL	UNDERGRAD DEGREE	COMPUTER EXPERIENCE	COMPUTER AND LANGUAGE	PROGRAM TYPE
BEGINNING	E.E.	MINIMAL	IBM 370 CSMP	POINT BY POINT
BEGINNING	E.E.	MINIMAL	IBM 370 APL	POINT BY POINT
BEGINNING	PHYSICS	MINIMAL	DEC POP 10 FORTRAN	POINT BY POINT
ADVANCED	BIOLOGY	NONE	DEC LINC8 FOCAL	COMBINATION
ADVANCED	E.E.	SUBSTANTIAL	DEC LINC8 FOCAL	INTEREST. TIME
ADVANCED	E.E.	SUBSTANTIAL	DEC LINC8 FORTRAN	TABLE LOOKUP
ADVANCED	PHYSICS	SUBSTANTIAL	DEC POP 10 FORTRAN	POINT BY POINT

Figure 2

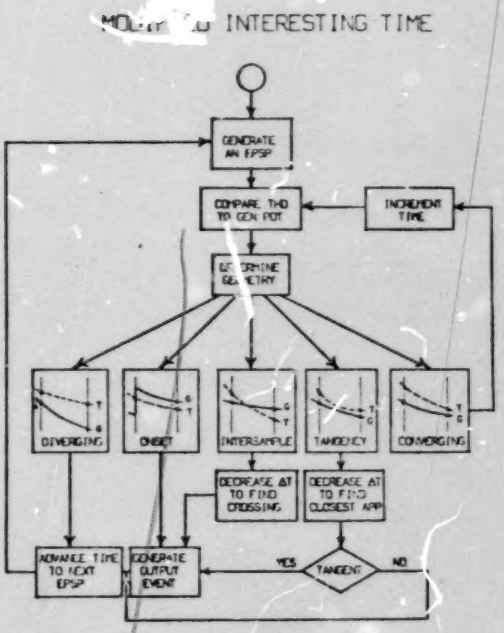

Figure 3

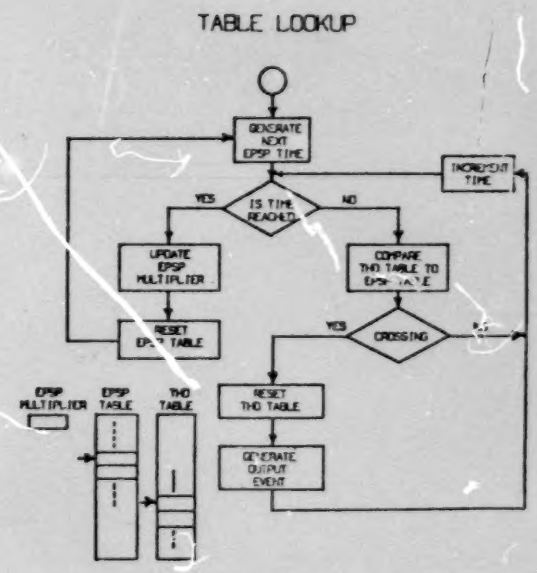

Figure 4

```
>>
FOR NUMBER EPSP CONTROL TYPE 1
FOR NUMBER SPIKES CONTROL TYPE 2
?1
ENTER TOTAL EPSPS
:100
ENTER LAMBDA:.03
X= 0.100064E+03
XXX= 0.519015E+02
XX= 0.104495E+02
XXXXXXX= 0.131995E+03
XX= 0.195209E+02
XXXXX= 0.736402E+02
XX= 0.130067E+02
XX= 0.230260E+02
XXXXX= 0.935734E+02
XX= 0.178917E+02
XXXXXXX= 0.134075E+03
XX= 0.211602E+02
XXXX= 0.834722E+02
XX= 0.163637E+02
XXXXXXX= 0.130950E+03
XX= 0.194237E+02
XXXXX= 0.751947E+02
XX= 0.149258E+02
XX= 0.229142E+02
XXXXX= 0.929207E+02
XX= 0.178007E+02
XXXXXXX= 0.152264E+03
XX= 0.210563E+02
XXXXX= 0.829519E+02
XX= 0.162781E+02
XXXXXXX= 0.129937E+03
XX= 0.193265E+02
TOTAL NUMBER EPSPS= 0.100000E+03
TOTAL NUMBER SPIKES= 0.210000E+02
TOTAL TIME ELAPSED= 0.152233E+04 MSEC
AVG EPSP RATE= 0.6568[illegible]E-01 EPSPS/MSEC
AVG FIRING RATE= 0.13[illegible]E-01 SPIKES/MSEC
DONE
*
```

Figure 5

Figure 6

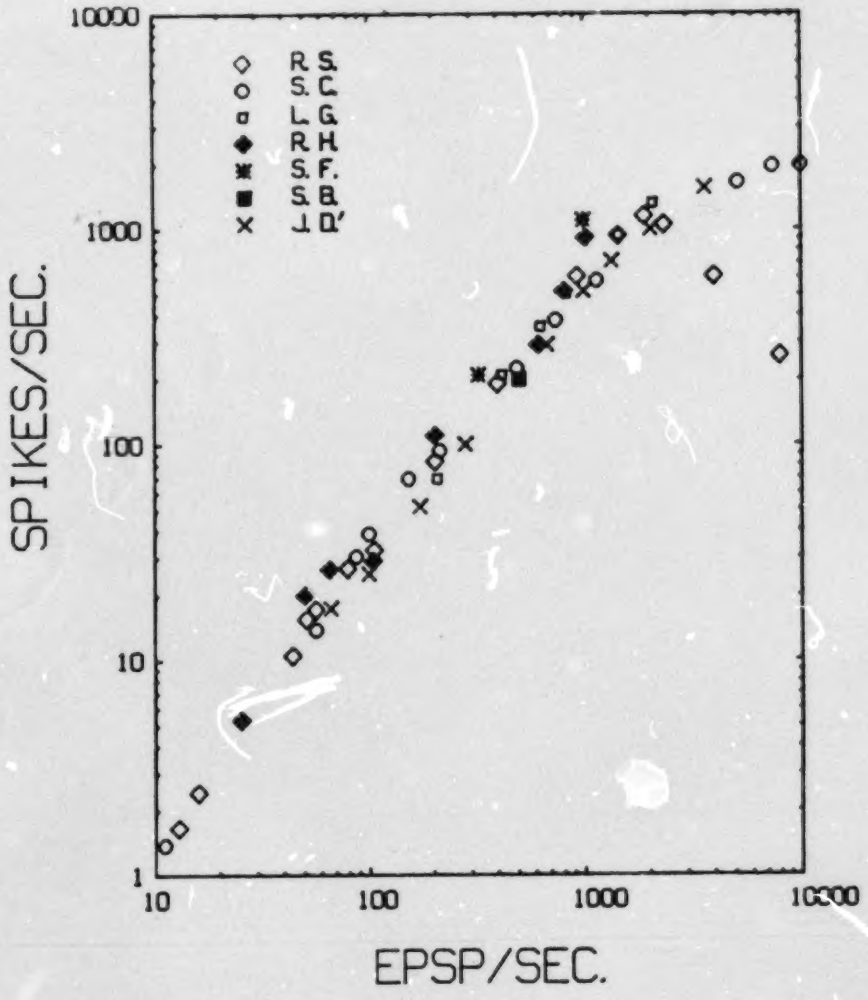
10000
1000
100
10
1
10
100
1000
10000
SPIKES/SEC.
EPSP/SEC.
R S.
S. C.
L G.
R H.
S. F.
S. B.
T D'

Figure 7